Model for Statewide Freight Transportation Planning

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A planning model for statewide freight transport systems planning is proposed that is a modification of the existing and readily available Urban Transportation Planning System (UTPS) package. The model is modified in such a way that it can be used for the analysis of multicommodity freight flows by highway, rail, water, and pipeline for a region and/or a state. The issues and problems that can be analyzed by using the model include the identification of the anticipated impacts of deregulation, rail mergers, a shift in the economic base of an area, and changes in population, transportation rate, energy availability, and service.

The state of the art of analyzing freight demand at the state level is primitive, and techniques are not readily available to state agencies for direct application (1). Because of this paucity of analytic techniques, as well as a lack of freight flow data, state agencies have not been able to adequately address and identify the anticipated impacts of deregulation, rail mergers, shift in the economic base of an area, and changes in population, transportation rate, energy availability, and service.

The purpose of this paper is to propose a multicommodity, multimodal statewide freight transportation planning model by modifying the existing Urban Transportation Planning System (UTPS) package developed by both the Federal Highway Administration (FHWA) and the Urban Mass Transportation Administration (2).

Little effort, if any, has been devoted to the use of UTPS for freight transport planning and/or regional transportation planning. This is not surprising since the main thrust of UTPS was urban transportation planning in general and passenger transportation planning in particular. A number of studies, however, explored the similarities and dissimilarities between freight and passenger transportation modeling processes in the late 1960s (3-5). At the same time, Peat, Marwick, Livingston, and Company (6) has attempted to assign aggregate commodity traffic into geocoded freight networks and the Office of Systems Analysis and Information of the Office of the Secretary of Transportation initiated a pilot study to develop a network analysis methodology (7).

The Federal Railroad Administration (FRA) developed a computer network model in 1973 specifically for railroad planning, using the FHWA highway assignment program package as the basis.

These studies resulted in models that used partial phases of the entire urban transportation planning (UTP) processes. A number of studies have suggested the integration of goods movement into the appropriate phases of the UTP processes (8-10).

The first known application of network analysis techniques to freight movement by a state was performed in 1975 by the Pennsylvania Department of Transportation (PennDOT) (11). Although a systematic process was developed for assigning interzonal traffic flows, the assignment procedure does not rely on theory or algorithms for route decision-making and thus could possibly be influenced by subjective biases (1).

In a step toward building a comprehensive interregional commodity flow model, Boyce and Hewings (12) recently developed an entropy formulation for interregional commodity flows, including specific functions for modal split and route choice that are comparable to existing entropy models for passenger transport planning.

The models in the studies cited above remain either urban in scope, nonnetwork in nature or single-mode, or a model yet to be tested. However, a network model for interregional freight transport was developed by CACI-Federal for the Transportation Systems Center (13). Benefits that can be obtained from the model developed by CACI are acknowledged, but it is not the purpose of this paper to develop "another" network model to be applied for the evaluation of the statewide transportation system. Rather, the main purpose of the study is to use the existing program package as much as possible at the minimum cost of operation. The familiarity of many state transportation planners with UTPS will preclude the need for extensive training to use the modified UTPS model.

MODIFICATION OF UTPS FOR STATEWIDE FREIGHT TRANSPORT PLANNING

The overall flows of the proposed model, as well as appropriate modification and addition to UTPS, are shown in Figure 1. The proposed model is divided into five submodels as follows:

1. Network analysis models,
2. Freight transport demand analysis models,
3. Vehicle requirements models,
4. Assignment model, and
5. Evaluation model.

Network Analysis Models

The geography assumed for the model is either the Bureau of Economic Analysis (BEA) areas, counties, or subcounty units. Preference should be given to the smaller unit if the flow data can support this level of detail.

Coding and Building Networks

Freight is shipped by three main transport modes: highway, rail, and waterway. In addition, it is anticipated that pipelines will play an increasing role in shipping commodities. In coding and building networks for the freight transport system, the UTPS.HR program will be modified and used.

At first, it might seem that the rail network should be built by using the UTPS.UNET program. However, this program implies the representation of transit lines that have the following properties:

1. A transit line is served by vehicles operating at regular intervals. In general, freight rail movements are not regular.
2. Transit lines imply two-way movements of vehicles on the same route. This does not correspond to freight rail operating practice.

Railroad, pipeline, and waterway networks for freight are built by UTPS.HR by specifying area types and facility types for each link, as shown in Figure 2. Speed by lane, area, and facility type should be provided by "look-up" tables in UTPS.UROAD for corresponding modes.

Path Building and Skimming

The network will be processed by UROAD to yield zone-to-zone impedance for the different modes under consideration. The derived impedance will be a function of travel time, including transfer times and travel costs. Different values of composite impedance may also be calculated by using the weighting options of UROAD for travel time, travel costs, and toll facilities.

Freight Transport Demand Analysis Models

As in standard UTPS procedures, freight transport demand analyses will be divided into four steps: freight volume generation, interzonal commodity distribution, modal split, and freight volume assignment. The basic decision unit will be metric tons in each step except in the final assignment stage, where the volume in metric tons will be converted into vehicle equivalents for each mode (trucks of different sizes, rail cars, barges, etc.).

Freight volume origin-destination (O-D) data between BEA regions are available (14,15). These are

Figure 1. Modification of UTPS for statewide transportation planning.

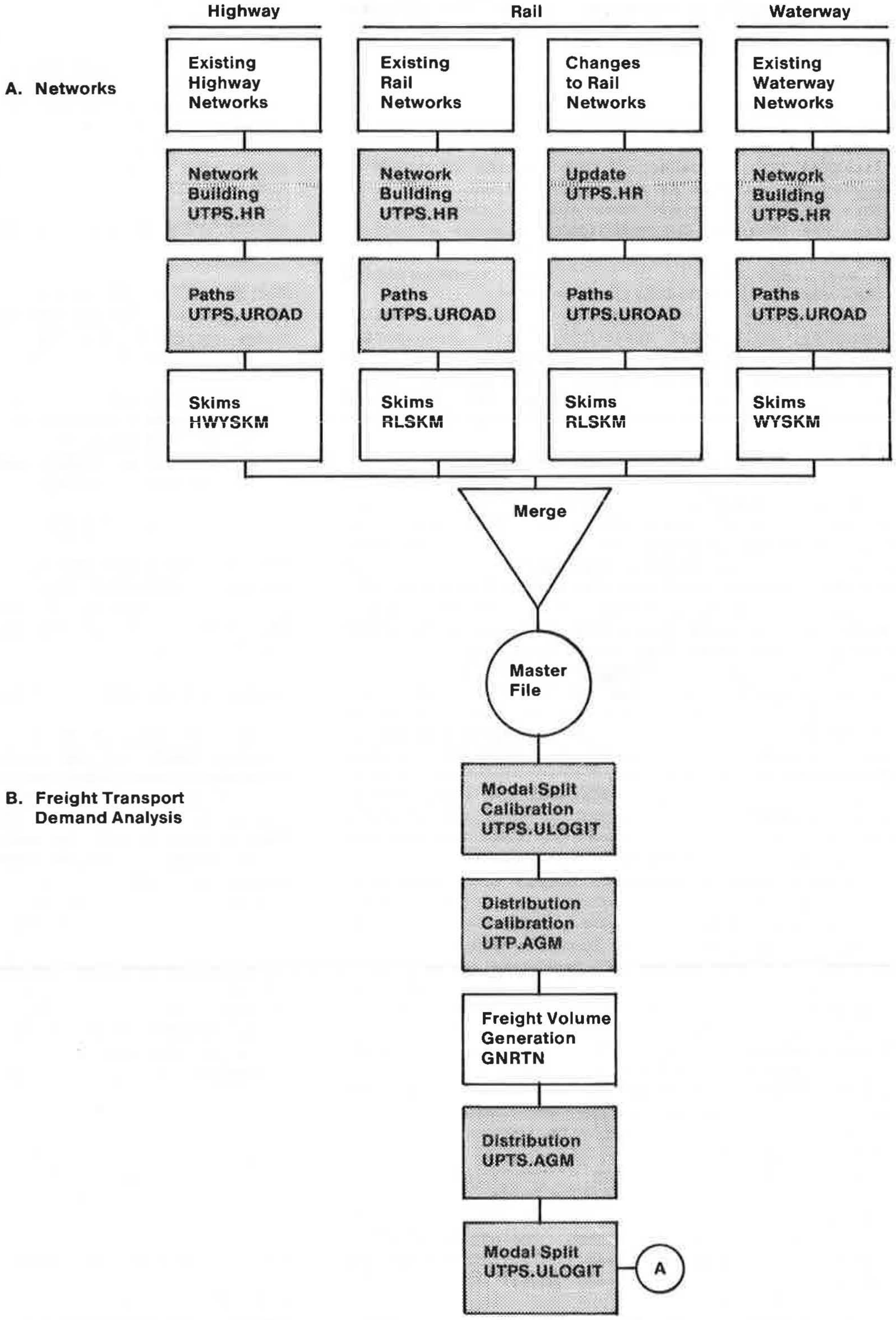

Figure 1. Continued.

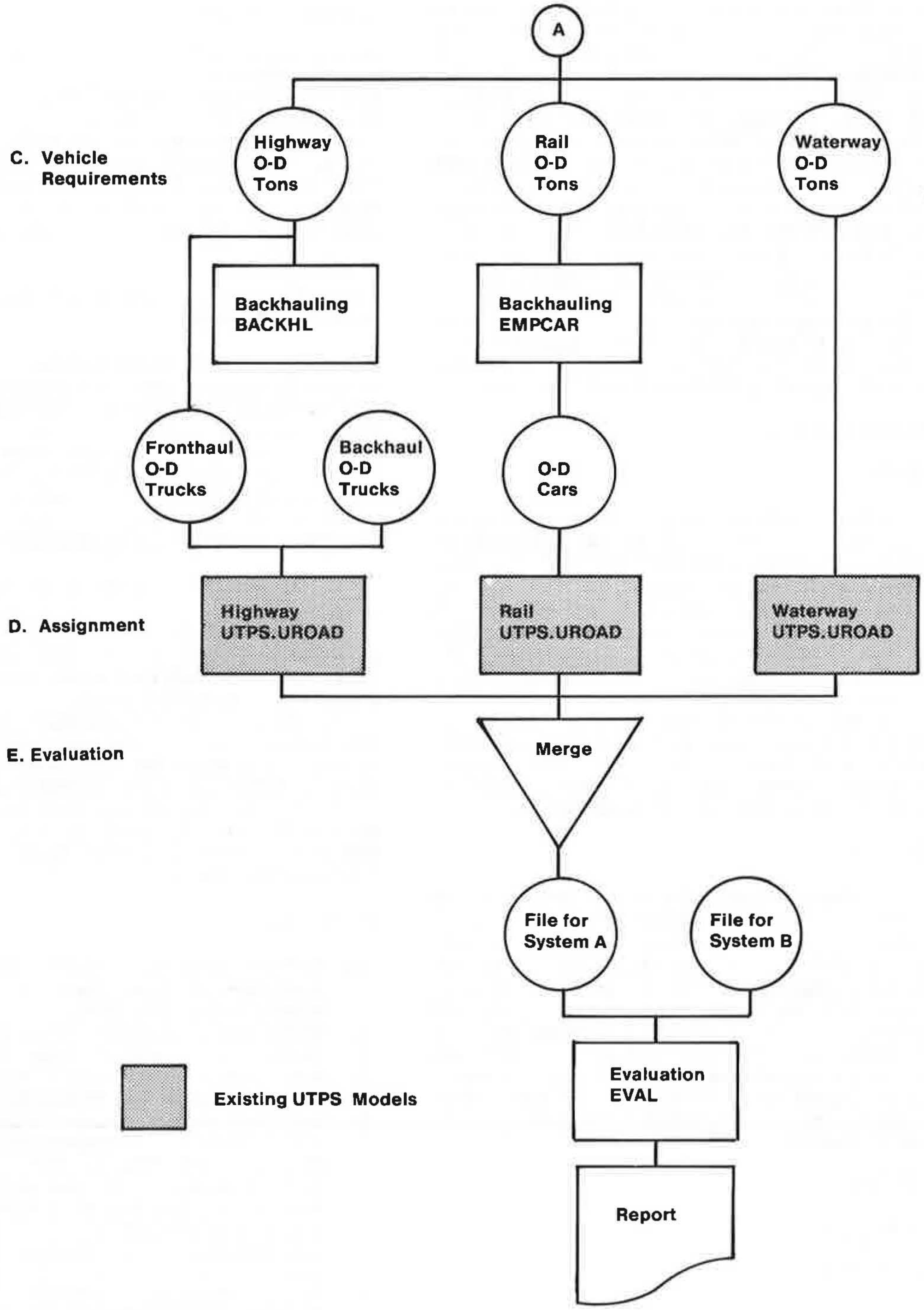

Figure 2. Sample representation of different modes by type of area and facility in UTPS.HR.

Remarks	Area Type / Facility Type	Mountainous	Hilly	Flat	Populated	Water/ Special
Access Link	1. Connector	Highway				Pipeline
Two Lane	2. Undivided Expressway					
Four Lane	3. Divided Expressway					
Rail or Waterway	4. Rail or Barge	Rail				Barge

part of data that were prepared for DOT, and thus no extensive data collection efforts are necessary for the analysis of BEA regions. Data by county for some commodities are available in many states. For example, in Illinois, coal (16) and grain movements (17,18) by rail, highway, or water are available. Data on fertilizer and petrochemical shipments at the county level were collected by the Illinois DOT and its Bureau of Railroads and Bureau of Planning.

For calibration of modal split and commodity distribution, UTPS.ULOGIT and UTPS.AGM will be used without much modification. For freight volume generation, either existing UTPS models (UMODEL and/or UFIT) will be used or a separate program can be developed if necessary according to the need of each state. For interzonal commodity distribution, UTPS.AGM will be used without significant modification. For modal split, UTPS.ULOGIT will be used.

Vehicle Requirements Models

Truck Backhaul

A backhaul model, which is not provided in the standard UTPS package, is essential to the modeling of highway freight movements because backhaul directly affects the traffic to be carried by the highway networks and also truck operating efficiency. A probabilistic type of model can be developed that calculates the probability of truck backhauling, depending on volume to be carried, distance, truck size, and cost of backhauling. If such data are unavailable, a few sample weight station surveys or truck company surveys will be sufficient and only six variables will have to be identified: origin and destination, volume carried, commodity carried, distance, truck size, and cost of backhauling.

Empty Rail Cars

Conventional transportation planning models provide estimates of the number of loaded cars required to carry freight in each direction. However, freight flows will be different in opposite directions, and there will be a requirement for the movement of empty rail cars in order to equalize their supply and demand locally. These empty-car movements must be estimated since they require system capacity and contribute to the operational costs of the railroad.

A separate linear programming type of cost minimization model can be developed, the concept for which is expressed as

$$\text{Min } Z = \sum_{i \neq j} \sum_{i \neq j} C_{ij} E_{ij}$$

subject to $E_{ij} \geq 0$:

$$\sum_{j \neq i} (F_{ij} + E_{ij}) = \sum_{j \neq i} (F_{ji} + E_{ji})$$

where

E_{ij} = number of empty cars to be hauled from i to j,
F_{ij} = number of full cars required to be hauled from i to j, and
C_{ij} = cost of hauling one empty car between i and j.

Assignment Model

After interzonal commodity flow tonnages are converted into fronthaul and backhaul trucks or rail cars, the application of UTPS.UROAD will result in the assignment of trucks or cars to the different networks.

Evaluation Model

An evaluation model is not available in UTPS, even for the passenger systems. This model is necessary for the evaluation of the impact of such policies as deregulation on freight transportation systems from the state's perspective as well as from the shipper's. A separate evaluation model will include, but not be limited to, the following criteria: (a) benefits to the public (consumer surplus), (b) accessibility, (c) vehicle utilization, and (d) energy consumption.

IMPLICATIONS FOR STATEWIDE FREIGHT TRANSPORT PLANNING

The modified UTPS model suggested in this paper for statewide freight transport purposes was applied for the national comprehensive transportation study for Korea (19). No application has been made, however, to any state in the United States as yet. Notwithstanding the fact that UTPS is an urban and passenger-oriented model, the potential and practical benefits of modifying it for statewide freight transport purposes are as follows:

1. No extensive development work will be necessary.
2. Many transportation planners, including those in state agencies, are familiar with UTPS. This implies that the modified model would not involve extensive dissemination costs.
3. Once statewide transport networks are coded, the network can be used for both freight and passenger transportation analyses since the network will be coded and built in UTPS frameworks.
4. The results of the proposed study can be used as a basis for the development of a "Statewide Comprehensive Transportation Systems" package within the UTPS framework.

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Importance of Empty Backhauling and Special Services to Cost of Exempt Truck Service

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Exempt motor carriers often provide a number of special services (such as multiple pickups, paying for loading and unloading, and multiple deliveries) at little or no charge. These services allow greater flexibility in the shipping of agricultural commodities. However, these services carry a significant cost for the carrier, and, because the truck service buyer does not bear these costs through an additional charge, he has no incentive to limit the number of services he requires. Because these practices are uncommon in other sectors of trucking, it is proposed that much of the cost of these services represents a resource misallocation. Empirical evidence taken from the Florida produce truck service market is used as an example of the significance of these costs. A second issue addressed is the cost of empty backhauling by returning exempt carriers. In the market studied (the Florida produce market), regulation, rather than a natural commodity flow imbalance, appears to be causing empty backhauling. Although empty backhauling inefficiently increases the average cost of truck service, more importantly, it distorts the values paid for agricultural truck service. Empirical evidence collected from the Florida market is used to show that the distortion of prices is much more important than the average costs of inefficient empty backhauling.

It is common for carriers of perishable agricultural commodities to provide multiple pickups and deliveries with tractor-semitrailers. In addition, carriers often provide loading and unloading services by hiring freelance labor at shippers' and/or receivers' docks. The willingness of agricultural carriers to provide such "special services" at no charge or little charge has been hailed as a benefit of agricultural exemption from motor carrier regulation (1). On the other side of the coin, on return trips agricultural carriers often have to backhaul empty. The problem of empty backhauling is often attributed to too much regulation, the argument being that carriers without regulated authority who haul exempt agricultural commodities cannot return with regulated commodities (2). The fact that most commodities bound for agricultural areas are regulated promotes an imbalance in flows of commodities that agricultural carriers may haul on their fronthauls and backhauls.

The intent of this paper is twofold. The first purpose is to show that the existing pricing structure of produce truck service is causing a resource misallocation. Because each additional special service is not priced at its cost, the buyers of truck services do not bear the cost of requiring added special services. Hence, buyers are not being given the proper pricing signals to make efficient choices and a resource misallocation results. Furthermore, estimates of the costs of special service will be used to show that these costs are quite significant. The second purpose of the paper is to shed new light on the costs of regulatory constraints that cause empty backhauling. Typically, the costs of empty backhauling are assumed to be equal to the average costs of truck travel times the empty miles traveled. However, the situation is more complex than this. Regulation causes an artificial scarcity of truck suppliers bound for agricultural areas and results in a distortion of truck service markets in both directions (inbound and outbound). An example is used to show that the distortion of the markets causes a greater burden on agricultural truck-service buyers than just average costs of empty backhauling.

FREIGHT MARKET

The area investigated was the Florida produce truck-service market. During 1978-1979, Florida produce shippers depended almost totally on truck transpor-